3

Physics & Engineering

Program Library

Astronomy
Statics & Dynamics
Relativity
Mechanics
Properties of Matter
Fluids
Structures
Thermodynamics



Physics & Engineering

3

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How to use these programs

Each program is arranged as follows:

- On the left of the page, explanatory information and the 'execution sequence', the sequence of keystrokes necessary for running the program. Results displayed are printed in gold.
- 2. In the first column on the right hand side of the page, the sequence of keystrokes which make up the program.
- 3. In the second and third columns on the right hand side of the page, the program in check symbol and step number form (see section on checking the program).

Notes

 Where a key has more than one function, the relevant function is printed as the keystroke in the first column

e.g. the keystroke B may appear as 8, cos or arccos.

2. The symbol ▼ within a program always refers to the key \(\frac{1}{\frac{1}{2}}\)/EE/-

3. The symbol # refers to 3

4. The abbreviation gin is 'go if neg' and so refers to the key 1

Entering the program

To enter a program into the calculator:

1. Press av 2 0 0 Display shows step programmed at 00 in check symbol form as described below.

2. Press ►▼ RUN No change in display.

 Press the sequence of keys for the program as shown in the first column of the program page.

At each stage the step about to be overwritten is displayed. When the machine is first switched on every step is zero.

4. Press C/CE Normal number display is resumed.

5. Press 🗗 🛕 2 0 0 The step programmed at 00 will be displayed.

Checking the program

Each of the programs in the library is shown in check symbol form in the second column on the right-hand side of the page.

Press AV C/CE repeatedly, and at each stage the check symbol will appear on the left of the display with the step number on the right. Ignore the four zeros in the display.

e.g.

A.0000 03

check symbol step number

After stepping through the program, press

AV

before execution.

go to Finally, press C/CE and the program is ready for use.

Correcting the program

If the check symbol for a particular step number is not as indicated in the last two columns of the program page:

1. Press

followed by the step number if the appropriate step number is not already displayed.

learn 2. Press ▲▼ RUN

- Enter the correct keystroke. The display will then show the next 3. step in the program. If this is also incorrect, enter the correct keystroke. At each stage, the step about to be overwritten will be displayed.
- 4. When correction has been completed, press C/CE. Any step which has not been overwritten will not be affected.

5. Press ▲▼

AV

2

Note

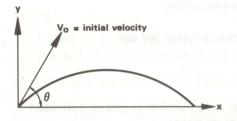
To restore normal use of the calculator after entering or checking the program, press C/CE

Running the program

Press the sequence of keys as shown in the program library in the execution sequence. Results displayed are printed in gold.

PROJECTILES

Position relative to point of projection after time t



$$x = v_0 t \cos \theta$$

$$y = v_0 t \sin \theta - \frac{gt^2}{2}$$

Execution:

 θ° / RUN / v_{o} / RUN / t / RUN / \times / RUN / y

V A 000 D→R 3 01 sto 2 02 tan 9 03 X 04 6 05 rcl 5 06 06 cos 8 07 07 X 08 08 09 X 10 09 X 10 09 X 10 11 stop 0 14 - F 15 (6 16 rcl 5 17 X 19 # 3 20 4 4 21 . A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 32 0 0 32 0 0<	_	Α.	00
sto 2 02 tan 9 03 X	•	A	00
tan 9 03 X 04 (6 05 rcl 5 06 cos 8 07 X 08 stop 0 09 X 10 stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 ∴ A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34			97723 med
X · 04 (6 05 rcl 5 06 cos 8 07 X · 08 stop 0 09 X · 10 stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X · 18 X · 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34			
(6 05 rcl 5 06 cos 8 07 X 08 stop 0 09 X 10 stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34		9	Same Co
rcl 5 06 cos 8 07 X 08 stop 0 09 X 10 stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 - 26) 6 27 - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34		•	
cos 8 07 X			A - 1 55-6 3
X	rcl		1
stop 0 09 X 10 stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 - 26) 6 27 - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	cos	8	
X	X		80
stop 0 11 sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	stop		09
sto 2 12) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	X	•	10
) 6 13 stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 - A 22 9 9 23 0 0 24 5 5 25 - 26) 6 27 - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	stop	0	9 500
stop 0 14 - F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 - A 22 9 9 23 0 0 24 5 5 25 - 26) 6 27 - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	sto	2	
- F 15 (6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34)	6	13
(6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	stop	0	
(6 16 rcl 5 17 X 18 X 19 # 3 20 4 4 21 · A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	ave Tenor	F	15
rcl 5 17 X 18 X 19 # 3 20 4 4 21	(6	16
X	rcl	5	17
# 3 20 4 4 21			18
4 4 21 A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	X		19
A 22 9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	#	3	20
9 9 23 0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	4	4	21
0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34		Α	22
0 0 24 5 5 25 = - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	9	9	23
= - 26) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	0	0	24
) 6 27 = - 28 stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34	5	5	25
=	anto n	9-	26
stop 0 29 ▼ A 30 goto 2 31 0 0 32 0 0 33 34)	6	27
▼ A 30 goto 2 31 0 0 32 0 0 33 34	= 0	0	28
goto 2 31 0 0 32 0 0 33 34	stop	0	29
goto 2 31 0 0 32 0 0 33 34		Α	30
0 0 32 0 0 33 34	goto		19 63.3
0 0 33	State of the state of	0	32
34			33
35			34
	pupss		35

PROJECTILES

Range, maximum height and time of flight

$$T = \frac{2v_o}{g} \sin \theta$$

$$R = \frac{2v_o^2}{g} \sin \theta \cos \theta$$

$$H = \frac{v_o^2}{2g} \sin^2 \theta$$

Execution:

 θ° / RUN / v_{\circ} / RUN / time of flight / RUN / maximum height / RUN / range

•	Α	00
D→R	3	01
sto	2	02
sin	7	03
X	•	04
stop	0	05
×		06
#	3	07
1,10	Α	08
2	2	09
0	0	10
4	4	11
X		12
stop	0	13
×	•	14
#	3	15
1.8	1	16
410 TY	A	17
2	2	18
2	2	19
6	6	20
÷	G	21
stop	0	22 23
(6	23
rcl	5	24
tan	9	25
)	6	26
+	Е	27
+	Е	28
+ = stop	-	29
stop	0	30
•	Α	31
goto	2	32
0	0	33
0	0	34
100		35

PROJECTILES

Necessary angle of projection for given range with given speed of projection

 $\sin 2\alpha = \frac{Rg}{v^2}$ giving two possible angles α_1 and α_2 .

Execution:

v / RUN / R / RUN / α⁰ / RUN / α⁰ 2

X	•	00
÷	G	01
X	•	02
#	3	03
9	9	04
•	Α	05
8	8	06
1	1	07
X	•	80
stop	0	09
=	_	10
	Α	11
arcsin	7	12
V	Α	13
R→D	3	14
÷	G	15
#	3	16
2	2	17
-	F	18
stop	0	19
#	3	20
9	9	21
0	0	22
_	F	23
0 = 110	-	24
stop	0	25
▼	A	26
goto	2	27
0	0	28
0	0	29
U	0	30
		31
		32
		33
		34
	-	
		35

PARALLELOGRAM LAW FOR FORCES

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \alpha}$$

Execution:

 $P/RUN/Q/RUN/\alpha^{\circ}/RUN/R$

Range: $0 \le \alpha^{\circ} \le 180^{\circ}$

E may appear if α is close to 0° or 180°

sto	2	00
stop	0	01
X		02
(6	03
+	E	04
rcl	5	05
=	_	06
•	Α	07
MEx	5	08
)	6	09
X		10
(6	11
stop	0	12
rizorless	F	13
#	3	14
9	9	15
0	0	16
_	F	17
=	-	18
V	F - A 3	19
D→R	3	20
sin	7	21
_100	F	22
#	3	23
1	1	24
+	Е	25
)	6	26
+	Ε	27
(6	28
rcl	5	29
X		30
)	6	31
=	_	32
\sqrt{x}	1	33
stop	0	34
=	_	35

CONSTANT ACCELERATION MOTION

u = initial velocity

v = final velocity

s = distance covered

f = acceleration

t = time

$$v = u + ft$$

$$s = ut + \frac{ft^2}{2}$$

Execution:

t/RUN/f/RUN/u/RUN/v/RUN/s

X	•	00
(6	01
X		02
stop	0	03
÷	G	04
#	3	05
2	2	06
+	Е	07
sto	2	80
+	Е	09
stop	0	10
	F	11
stop	0	12
rcl	5	13
)	6	14
=	-	15
stop	0	16
	Α	17
goto	2	18
0	0	19
0	0	20
1 10	18	21
. 0	100	
	100	22
1	8	22 23
1	8	
, -	£,	23
stup	E. 0	23 24
stup	F. 0	23 24 25
stop	0 A 2	23 24 25 26
ston 9 9000 0	8. 0 8. 2	23 24 25 26 27
2010 9	6 0	23 24 25 26 27 28
# 0010 0	6 0 0	23 24 25 26 27 28 29
2010 9 9010 0	6 A 2 8 0	23 24 25 26 27 28 29 30 31 32
stos y goto 0	6 0 A 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	23 24 25 26 27 28 29 30 31
2100 9 9 0010 0	F. 0	23 24 25 26 27 28 29 30 31 32

CONSTANT ACCELERATION MOTION

For notation see page 12

$$v = \sqrt{u^2 + 2fs}$$

Execution:

u/RUN/f/RUN/s/RUN/v

This gives the absolute value of v; other considerations must be used to determine the correct sign.

X	1	00
+	E	01
(6	02
stop	0	03
X		04
stop	0	05
+	E	06
)	6	07
98 (1)	1	08
\sqrt{X}	1	09
stop	0	10
	Α	11
goto	2	12
0	0	13
0	0	14
	1237	15
1/41/	1764	16
	6	17
	-	18
stáp	0	19
100	itim	20
		21
1 341.		22
	2	23
	7	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

CONSTANT ACCELERATION MOTION

For notation see page 12

(i)
$$t = \frac{v - u}{f}$$
$$s = \frac{v^2 - u^2}{2f}$$

Execution:

v/RUN/u/RUN/f/RUN/t/RUN/s

(ii)
$$f = \frac{v - u}{t}$$

Execution:

v/RUN/u/RUN/t/RUN/f/RUN

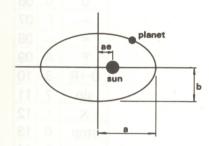
(iii)
$$f = \frac{v^2 - u^2}{2s}$$

Execution:

v/RUN/u/RUN/s/RUN/RUN/f

-	F	00
stop	0	01
sto	2	02
÷	G	03
(6	04
÷	G	05
#	3	06
2	2	07
+	Е	08
rcl	5	09
=	9	10
sto	2	11
stop	0	12
)	6	13
×	•	14
stop	0	15
rcl	5	16
=:00	TIUC	17
stop	0	18
•	Α	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

PLANETARY MOTION



Kepler's law: orbit is an ellipse with sun at one focus.

$$r = \frac{p}{1 + e \cos \theta} = \frac{b\sqrt{1 - e^2}}{1 + e \cos \theta} = \frac{b^2}{a(1 + e \cos \theta)};$$

$$e^2 = 1 - \frac{b^2}{a^2}$$

Execution:

 θ° / RUN / e / RUN / p / RUN / r

X	•	00
=	_	01
\sqrt{x}	1	02
-	F	03
#	3	04
9	9	05
0	0	06
_	F	07
=	-5	08
•	Α	09
D→R	3	10
sin	3	11
X	•	12
stop	0	13
+	E	14
#	3	15
1	1	16
•	G	17
X		18
stop	0	19
=	_	20
stop	0	20 21 22
▼ :	Α	22
goto	2	23
0	0	24
0	0	25
sin	7	26
		27
		28
1	3	29
1. 1		30
	6	31
F03	18	32
4	9	33
		34
stóp.	-01	35
-	-	-

PLANETARY MOTION X 00

For notation see page 15

Execution:

 θ° / RUN / e / RUN / b / RUN / r

X	•	00
=	_	01
\sqrt{x}	1 F	02
_	F	03
#	3	04
9	9	05
0	0.	06
-	F	07
=	_	80
•	Α	09
D→R	3	10
sin	F - A 3 7	11
X	•	12
stop	0	13
sto	2	14
+	E	15
#	3	16
1/5	1	17
gil÷ na	G	18
X	•	19
(6	20
rcl	5	21
X	•	22
- + #	F E	23
+	E	24
#	3	25
9 1 VIL	1	26
=	_	27
\sqrt{x}	1 - 1	28
# 1 = \sqrt{x}	6	29
X		30
stop	0	31
=	_	32
stop	0	33
=	_	34

PLANETARY MOTION

For notation see page 15

Execution:

b/RUN/a/RUN/θ°/RUN/r

sto	2	00
÷	G	01
stop	0	02
×	•	03
	A	04
MEx	5	05
	_	06
•	Α	07
MEx	5	08
•	Α	09
arcsin	A 7	10
cos	8	11
X	o*=	12
v struc	6	13
stop	0	14
X	0.1=	15
vi t iols	o.*=	16
\sqrt{x}	1	17
)5 V <u>10</u> 8 Ck	1 F 3	18
#	3	19
9	9	20
0	0	21
78,	F	22
=.no	-	23
	Α	24
D→R	3	25
sin	3 7 6	26
)	6	27
+	E	28
+ #	3	29
1	1	30
÷	G	31
rcl	5	32
•	G	33
÷ = stop	_	34
stop	0	35

DOPPLER EFFECT (non-relativistic)

For sound waves, etc.

v_o = observer velocity

v_s = source velocity

f_s = transmitted frequency

f_o = observed frequency

c = velocity of wave

Given observed frequency, to find transmitted frequency.

$$f_s = \left(\frac{c + v_o}{c - v_s}\right) f_o$$

Execution:

c/RUN/v_o/RUN/v_s/RUN/f_o/RUN/f_s

sto	2	00
+	Е	01
stop	0	02
*	G	03
(6	04
rcl	5	05
<u>^</u>	F	06
stop	0	07
)	6	80
X	•	09
stop	0	10
=	_	11
stop	0	12
•	Α	13
goto	2	14
0	0	15
0	0	16
	1	17
136 14		18
X	2	19
	5	20
cci	- 6	21
		22
	-	23
		24
T B		25
	1	26
- 100		27
VX	1	28
		29
X		30
stop	0	31
100		32
5200	.0	33
100		34
190		35

DOPPLER EFFECT (non-relativistic)

For notation see page 18

Given transmitted frequency, to find observed frequency.

Execution:

c/RUN/v_s/RUN/v_o/RUN/f_s/RUN/f_o

sto ·	2	00
-	F	01
stop	0	02
÷	G	03
(6	04
stop	0	05
+	E	06
rcl	5	07
)	6	08
X		09
stop	0	10
=	9	11
stop	0	12
•	Α	13
goto	2	14
0	0	15
0	0	16
		17
1 ino	fuo	18
CEA I	7	19
		20
	9	21
		22
		23
FCI	3	24
7	A	25
aresin i		26
008	8	.27
	8	28
100		29
.510	2	30
900	0	31
	5	32
		33
stop	0	34
		35

DOPPLER EFFECT (non-relativistic)

For notation see page 18

Given both frequencies, to find source velocity.

Execution:

c/RUN/v_o/RUN/f_o/RUN/f_s/RUN/_{Vs}

2007	F	00
(6	01
+	E	02
stop	0	03
X		04
stop	0	05
÷	G	06
stop	0	07
)	6	80
=	-	09
stop	0	10
•	Α	11
goto	2	12
0	0	13
0	0	14
o imena		15
euman b		16
		17
11152	2134	18
F N sw N S		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
ŕ		30
		31
		32
		33
		34
		35

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

f_s = source frequency

f_o = observed frequency

 $c = \text{speed of light} = 2.997925 \times 10^8 \text{ms}^{-1}$

v = speed of source

θ = direction of motion of source relative to observer

$$f_o = f_s \frac{\sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{v}{c} \cos \theta}$$

Execution:

- (i) $v/RUN/c/RUN/\theta/RUN/f_s/X/RUN/f_o$
- (ii) $v/RUN/c/RUN/\theta/RUN/f_o/\div/AUA$

	0	00
÷	G	00
stop	0	01
X	•	02
sto	2	03
(6	04
stop	0	05
X		06
=	-	07
√x	1	80
-	F	09
#	3	10
9	9	11
0	0	12
19 = 191	80	13
•	Α	14
D→R	3	15
sin	7	16
)	6	17
+	Е	18
#	3	19
1115	1	20
÷	G	21
X	•	22
(6	23
rcl	5	24
	Α	25
arcsin	7	26
cos	8	27
)	6	28
=		29
sto	2	30
stop	0	31
rcl	5	32
=	-	33
stop	0	34
=	-	35

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

Source receding from observer at velocity v. Source frequency f_s , observed frequency f_o .

$$f_o = f_s \frac{\sqrt{1 - \frac{v^2}{c^2}}}{1 + \frac{v}{c}} = f_s \sqrt{\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}}$$

Given v and one frequency, to find the other frequency.

Execution:

- (i) $v/RUN/c/RUN/f_s/X/RUN/f_o$
- (ii) $v/RUN/c/RUN/f_o/\div/RUN/f_s$

÷	G	00
stop	0	01
14111	F	02
#	3	03
1	1	04
÷	G	05
(6	06
+	Е	07
#	3	08
2	2	09
-	F	10
)	6	11
=	_	12
\sqrt{x}	1	13
sto	2	14
stop	0	15
rcl	5	16
	_	17
stop	0	18
. ▼	Α	19
goto	2	20
0	0	21
0	0	22
2 3 3263	1 . 1	23
		24
s ditan	V	25
1 / 1/1	137	26
		27
		28
		29
		30
		31
		32
		33
		34
		35

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

To find v, given fo and fs.

Execution:

fo / RUN / fs / RUN / c / RUN / v

If the wavelengths λ_o and λ_s are known:

Execution:

 λ_s / RUN / λ_o / RUN / c / RUN / v

If v is negative, motion is towards observer.

÷	G	00
stop	0	01
X		02
	F	03
#	3	04
1	1	05
•	G	06
(6	07
+	E	08
#	3	09
2	2	10
_	F	11
)	6	12
X		13
stop	0	14
=	_	15
stop	0	16
•	Α	17
goto	2	18
0	0	19
0	0	20
- 1110	040	21
NUA	18	22
RUN	V	23
LETTE		24
1 9 1 52 1 1	1 4	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

RELATIVITY

Fitzgerald contraction, time dilation and mass change.

$$T' = T \left(1 - \frac{v^2}{c^2} \right)^{\frac{1}{2}}$$

$$L' = L \left(1 - \frac{v^2}{c^2} \right)^{\frac{1}{2}}$$

$$M' = M \left(1 - \frac{v^2}{c^2} \right)^{-\frac{1}{2}}$$

Execution:

- (i) v/RUN/c/RUN/T/X/RUN/T
- (ii) v/RUN/c/RUN/L/X/RUN/L
- (iii) v/RUN/c/RUN/M/÷/RUN/M'

÷	G	00
stop	0	01
X		02
_	F	03
+	Е	04
#	3	05
1	1	06
=	_	07
√x	1	80
sto	2	09
stop	0	10
rcl	5	11
=	_	12
stop	0	13
. ▼	Α	14
goto	2	15
0	0	16
0	0	17
a latea la	ia.	18
1		19
fonaleve	ry er	20
0	0	21
7.110		22
NINGIE	UR	23
egative, r	0 9	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35
		33

LORENTZ TRANSFORMATION

(i)
$$X' = \frac{X - \beta cT}{\sqrt{1 - \beta^2}}$$

(ii)
$$T' = \frac{T - \frac{\beta X}{c}}{\sqrt{1 - \beta^2}}$$

where
$$\beta = \frac{v}{c}$$

Execution:

- (i) β / RUN / X / RUN / T / RUN / X'
- (ii) β /RUN/T/RUN/X/RUN/T'
- (b) Any consistent units

Execution:

- (i) v/÷/c/=/RUN/X/RUN/T/ X/c/RUN/X'
- (ii) v/÷/c/=/RUN/T/RUN/X/ ÷/c/RUN/T'

•	A	00
arcsin	7	01
sto	2	02
cos	8	03
÷	G	04
X		05
stop	0	06
_	F	07
(6	08
rcl	5	09
tan	9	10
X	•	11
stop		
8 1) 3	6	13
	_	17
stop		15
8 A UI		16
goto	2	17
0	0	18
0	0	19
		20
stop.		21
		22
affigia		23
		24
		25
		26
0		27
		28
		29
		30
		31
		32
		33
		34
		35

COMPOUND PENDULUM

T = period

k_o = radius of gyration about pivot

 k_g = radius of gyration about c.g.

r = distance from pivot to c.g.

l = length of simple equivalent pendulum

$$T = \frac{2\pi k_o}{\sqrt{gr}}$$

$$I = \frac{k_o^2}{r}$$

Execution:

r/RUN/k_o/RUN/T/RUN/I

√x	1	00
÷	G	01
X		02
stop	0	03
X	•	04
sto	2	05
#	3	06
2	2	07
	Α	80
0	0	09
0	0	10
6	6	11
1	1	12
=	-	13
stop	0	14
rcl	5	15
X		16
=	-	17
stop	0	18
•	Α	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
HV	111)	27
		28
		29
		30
		31
		32
		33
		34
		35

COMPOUND PENDULUM

Notation as on page 26

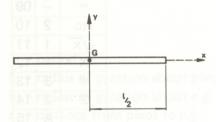
Use
$$k_o = \sqrt{k_g^2 + r^2}$$

Execution:

r/RUN/kg/RUN/T/RUN/I

sto	2	00
X		01
+	E	02
(6	03
stop	0	04
X		05
)	6	06
÷	G	07
rcl	5	08
=		09
sto	2	10
\sqrt{x}	1	11
X	•	12
	3	13
#	2	14
	Α	15
0	A 0	16
0	0	17
6	6	18
1	1	19
=	1	20
stop	0	21
rcl	5	22
stop	0	23
•	Α	24
goto	2	25
0	0	26
0	0	27
30 Jego 13	a (ja	28
nobied	q=	29
fettteb	51/-	30
to auto		31
goto	.2	32
	- 0	33
- 0	- 13	34
		35

Straight Rod



$$k_{xx}^2 = 0$$

$$k_{yy}^2 = \frac{l^2}{12}$$

Execution:

I/RUN/kyy

Notation throughout this section:

G = position of centre of gravity

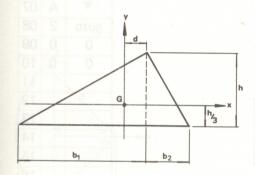
 k_{xx} = radius of gyration about x-axis through G

 k_{yy} = radius of gyration about y-axis through G

^		00
÷	G	01
#	3	02
1	1	03
2	2	04
=	_	05
stop	0	06
•	A	07
goto	2	08
0	0	09
0	0	10
		11
	1	12
	-	13
	10	14
		15
	3122	16
33		17
	0	18
* Inc	i pu	19
		20
Ö	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

X · 00

Triangular Lamina



For notation see page 28

$$d = \frac{b_1 - b_2}{3}$$

$$k_{xx}^2 = \frac{h^2}{18}$$

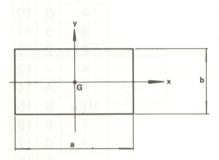
$$k_{yy}^2 = \frac{b_1^2 + b_1 b_2 + b_2^2}{18}$$

Execution:

 b_1 / RUN / b_2 / RUN / d / RUN / k_{yy}^2 / h / RUN / k_{xx}^2

X		00
(6	01
1-1	F	02
stop	0	03
sto	2	04
÷	G	05
#	3	06
3	3	07
X		08
stop	0	09
•	G	10
#	3	11
2	2	12
=	-	13
•	Α	14
MEx	5	15
)	6	16
÷	G	17
#	3	18
6	6	19
+	Е	20
rcl	5	21
=		22
stop	0	23
X		24
÷	G	25
#	3	26
1	1	27
8	8	28
= 1	u <u>y</u> r	29
stop	0	30
	Α	31
goto	2	32
0	0	33
0	0	34
	-	35

Rectangular lamina



For notation see page 28

$$k_{xx}^2 = \frac{b^2}{12}$$

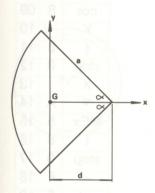
$$k_{yy}^2 = \frac{a^2}{12}$$

Execution:

 $b/RUN/k_{xx}^2/a/RUN/k_{yy}^2$

11		00
X		00
•	G	01
#	3	02
1	1	03
2	2	04
718 5 18	-	05
stop	0	06
•	Α	07
goto	2	08
0	0	09
0	0	10
		11
	-	12
		13
		14
100		15
		16
		17
		18
se anim	trons	19
		20
gd	+6	21
	8	22
	S.	23
	81	24
	27	25
guru T	111	26
01		27
-13.0	itis	28
	1 1114	29
\$0.7 KI	211	30
24.86	1 1	31
		32
		33
		34
		35

Sector of circular lamina



For notation see page 28

$$d = \frac{2a \sin \alpha}{3\alpha}$$

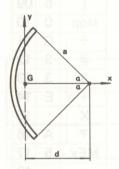
$$k_{xx}^2 = \frac{a^2}{4} \left(1 - \frac{\sin 2\alpha}{2\alpha} \right)$$

Execution:

 α (in radians) / RUN / a / RUN / d RUN / k_{xx}^2

sto	2	00
sin	7	01
÷	G	02
rcl	5	03
=	-	04
•	Α	05
MEx	5	06
cos	8	07
X		80
(6	09
stop	0	10
*	G	11
#	3	12
3	3	13
+	Е	14
X		15
•	A	16
MEx	5	17
=	_	18
stop	0	19
)	6	20
E DOBE	F	21
rcl	5	22
X	• 8	23
rcl	5	24
	F	25
X	•	26
#	3	27
9	9	28
÷ #	G	29
#	3	30
1	1	31
6	6	32
=	_	33
stop	0	34
=	_	35

Curved rod (arc of a circle)



For notation see page 28

$$d = a \frac{\sin \alpha}{\alpha}$$

$$k_{xx}^2 = \frac{a^2}{2} \left(1 - \frac{\sin 2\alpha}{2\alpha} \right)$$

Execution:

 α° / RUN / a / RUN / d / RUN / $k_{\star\star}^{2}$

•	Α	00
D→R	3	01
sto	2	02
sin	7	03
÷	G	04
rcl	5	05
=	_	06
•	Α	07
MEx	5	80
cos	8	09
X		10
(6	11
stop	0	12
X	•	13
- ▼	Α	14
MEx	5	15
)	6	16
stop	0	17
	F	18
rcl	5	19
X	٠	20
rcl	5	21
200 1100	F	22
÷	G	23
#	3	24
2	2	25
=	_	26
stop	0	27
▼	Α	28
goto	2	29
0	0	30
0	0	31
		32
		33
		34
		35

Spherical shell



For notation see page 28

a = radius

t = thickness

Volume = $4\pi a^2 t$

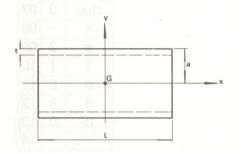
$$k_{xx}^2 = k_{yy}^2 = k_{zz}^2 = \frac{2a^2}{3}$$

Execution:

 $a/RUN/k_{xx}^2/t/RUN/volume$

X		00
·	G	01
#	3	02
1	1	03
•	Α	04
5	5	05
×		06
stop	0	07
X	•	08
#	3	09
1	1	10
0	0	11
8	8	12
0	0	13
=	_	14
•	Α	15
D→R	3	16
stop	0	17
•	Α	18
goto	2	19
0	0	20
0	0	21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
0	0	33
		34
		35

Thin-walled tube



For notation see page 28

a = radius

I = length

t = thickness

Volume = $2\pi alt$

$$k_{xx}^2 = a^2$$

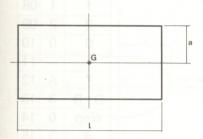
$$k_{yy}^2 = k_{zz}^2 = \frac{a^2}{2} + \frac{l^2}{12}$$

Execution:

 $I/RUN/a/RUN/t/RUN/volume/RUN/k_{xx}^2/RUN/k_{vv}^2$

X	•	00
+	E	01
(6	02
\sqrt{x}	1	03
X		04
stop	0	05
sto	2	90
X	•	07
stop	0	80
X	ं	09
#	3	10
3	3	11
6	6	12
0	0	13
=	=	14
	Α	15
D→R	3	16
\$top	0	17
rcl	5	18
X	•	19
X		20
stop	0	21
#	3	22
6	6	23
10 TA =	3271	24
)	6	25
÷	G	26
#	3	27
1	1	28
2	2	29
=	-	30
stop	0	31
=	-	32
=	_	33
=	_	34
		35

Solid cylinder



For notation see page 28

a = radius

I = length

Volume = $\pi a^2 I$

$$k_{xx}^2 = \frac{a^2}{2}$$

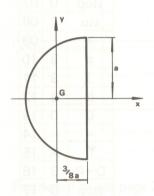
$$k_{yy}^2 = \frac{a^2}{4} + \frac{l^2}{12} = k_{zz}^2$$

Execution:

a / RUN / k_{xx}^2 / I / RUN / volume / RUN / k_{yy}^2

X	•	00
÷	G	01
÷ #	3	02
2	2	03
+	Е	04
(6	05
X		06
stop	0	07
sto	2	08
X	Ų.	09
#	3	10
3	3	11
6	6	12
0	0	13
=		14
•	A	15
D→R	3	16
stop	0	17
rcl	5	18
X		19
998÷1013	G	20
#	3	21
6	6	22
= '	_	23
)	6	24
÷ #	G	25
#	3	26
2	2	27
=	_	28
stop	0	29
•	Α	30
goto	2	31
0	0	32
0	0	33
		34
		35

Solid hemisphere



For notation see page 28

Volume =
$$\frac{2\pi a^3}{3}$$

$$k_{xx}^2 = \frac{2a^2}{5}$$

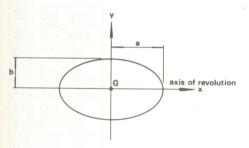
$$k_{yy}^2 = \frac{83a^2}{320}$$

Execution:

a / RUN / volume / RUN / k_{xx} / RUN / k_{yy}

sto	2	00
X		01
X	٠	02
(6	03
X		04
rcl	5	05
X		06
. #	3	07
1	1	80
2	2	09
0	0	10
=	_	11
•	Α	12
D→R	3	13
stop	0	14
#	3	15
	Α	16
4	4	17
i i=	8	18
)	6	19
X		20
stop	0	21
#	3	22
8	8	23
3	3	24
•	G	25
#	3	26
1	1	27
2	2	28
8	8	29
=	-	30
stop	0	31
=	_	32
=	_	33
=	_	34
=	_	35

Solid spheroid



For notation see page 28

(For sphere, a = b)

Volume =
$$\frac{4\pi ab^2}{3}$$

$$k_{xx}^2 = \frac{2b^2}{5}$$

$$k_{yy}^2 = \frac{a^2 + b^2}{5}$$

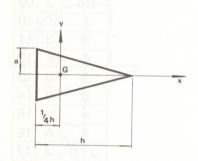
Execution:

b / RUN / k_{xx}^2 / a / RUN / volume / RUN / k_{yy}^2

X		00
X		01
#	3	02
	Α	03
4	4	04
+	Е	05
(6	06
X		07
stop	0	80
sto	2	09
X		10
#	3	11
6	6	12
0	0	13
0	0	14
=	_	15
•	Α	16
D→R	3	17
stop	0	18
rcl	5	19
X		20
X	10.1	.21
#	3	22
. 11	Α	23
4	4	24
=	_	25
)	6	26
÷	G	27
#	3	
2		28
	2	29
(1 = 26)	-	30
stop	0	31
=	-	32
=	13,830	33
=	1	34
=	_	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Solid cone



For notation see page 28

h = height a = radius of base

Volume =
$$\frac{\pi a^2 h}{3}$$

$$k_{xx}^2 = \frac{3a^2}{10}$$

$$k_{yy}^2 = \frac{3(4a^2 + h^2)}{80}$$

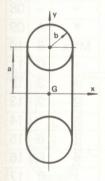
Execution:

a / RUN / k_{xx}^2 / h / RUN / volume / RUN / k_{yy}^2

	_			
X			0	0
X			0	
#	3		0:	2
•	Δ	1	03	3
3	3		04	1
+ (E		0	5
	6		06	
X			07	
stop	0		30	
sto	2		09)
X			10)
#	2		11	
2	2		12)
0	0		13	3
0 =	0		14	-
=	-		15	
•	А		16	,
D→R	3	I	17	
stop	3		18	N. N.
rcl	5	Ī	19	
X	Ge		20	
#	3		20 21	
	Α	1	22	
0	A 0	1	23	1
7	7		24	1
7 _ 5 =)	5 - 6	1	25	
=0.4	-		26	
)	6		27	1
÷	G	1	28	1
÷ #	3		29	-
2	2	1	30	
= stop	_	3	31	
stop	0	3	32	
=	_	3	33	
=	_		34	
=	_	3	35	

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Toroid (circular section)



For notation see page 28

Volume = $2\pi^2 ab^2$

$$k_{xx}^2 = a^2 + \frac{3b^2}{4}$$

$$k_{yy}^2 = \frac{a^2}{2} + \frac{5b^2}{8}$$

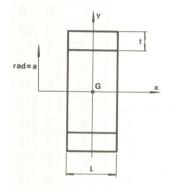
Execution:

b / RUN / a / RUN / volume / RUN / k_{xx}^2 / RUN / k_{yy}^2

X	a •	00
÷	G	01
#	3	02
4	4	03
=	_	04
sto	2	05
stop	0	06
X	•	07
+	E	08
(6	09
√x	1	10
X		11
rcl	5	12
X	A	13
#	3	14
7	7	15
8	8	16
•	Α	17
9	9	18
5	5	19
7	7	20
281R =	97718	21
stop	0	22
#	3	23
3	3	24
X		25
rcl	5	26
)	6	27
÷	G	28
stop	0	29
#	3	30
2	2	31
9 +X	Е	32
rcl	5	33
=	_	34
stop	0	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Toroid (rectangular section)



For notation see page 28

Volume = 2π atl

$$k_{xx}^2 = a^2 + \frac{t^2}{4}$$

$$k_{yy}^2 = \frac{a^2}{2} + \frac{t^2}{8} + \frac{l^2}{12}$$

Execution:

 $a/RUN/t/RUN/k_{xx}^2/I/RUN/k_{yy}^2$

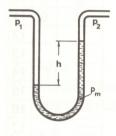
Post-execution (to find volume):

▲▼ / rcl / X / 6·2831852 / = / volume

sto	2	00
X		01
+	E	02
(6	03
stop	0	04
X		05
•	Α	06
MEx	5	07
=	-	08
•	Α	09
MEx	5	10
÷ #	G	11
#	3	12
2	2	13
X	•	14
)	6	15
+	E	16
(6	17
stop	0	18
X	•	19
•	Α	20
MEx	5	21
=	-	22
•	Α	23
MEx	5	24
X	•	25
÷	G	26
#	3	27
6	6	28
3 \ = \	1-1	29
)	6	30
_	G	31
#	3	32
2	2	33
=	_	34
stop	0	35

PRESSURE FLOW MEASUREMENT

Manometer



pressure difference $p_1 - p_2 = gh(\rho_m - \rho)$

Execution:

 $\rho_{\rm m}$ / RUN / ρ / RUN / h / RUN / pressure difference

In S.I. units; g taken as 9.81 ms⁻².

_	F	00
stop	0	01
X	•	02
stop	0	03
X		04
#	3	05
9	9	06
	Α	07
8	8	08
1	1	09
=	_	10
stop	0	11
•	Α	12
goto	2	13
0	0	14
0	0	15
		16
- Win		17
		18
19-9		19
Q.		20
		21
15.65		22
1101	11.19	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

FLOW RATES

Pitot static tube

u = velocity of fluid

P = total pressure

p = static pressure

 ρ = density

$$u = \sqrt{\frac{2(P - p)}{\rho}}$$

Execution:

P/RUN/p/RUN/ρ/RUN/u

stop 0 01 ÷ G 02 stop 0 03 + E 04 = - 05 √x 1 06 stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35	-	F	00
stop 0 03 + E 04 = - 05 √x 1 06 stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 34	stop	0	01
+ E 04 = - 05 √x 1 06 stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 - 12 - 13 - 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34	÷	G	02
+ E 04 = - 05 √x 1 06 stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	stop	0	03
√x 1 06 stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 26 27 28 29 30 31 32 33 34		E	04
stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	=	_	05
stop 0 07 ▼ A 08 goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	\sqrt{x}	1	06
goto 2 09 0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34		0	07
0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	•	Α	08
0 0 10 0 0 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	goto	2	09
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	10
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	11
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			12
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			13
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			14
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			15
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		1	16
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	einn	A	17
20 21 22 23 24 25 26 27 28 29 30 31 32 33			18
21 22 23 24 25 26 27 28 29 30 31 32 33	100	6	19
22 23 24 25 26 27 28 29 30 31 32 33 34	5.450		20
23 24 25 26 27 28 29 30 31 32 33 34	enstib	Bhui	21
24 25 26 27 28 29 30 31 32 33		10	22
25 26 27 28 29 30 31 32 33	1,35	7.45.69	23
26 27 28 29 30 31 32 33 34	181 N	J.Ph	24
27 28 29 30 31 32 33 34	everno	3.348	25
28 29 30 31 32 33 34			26
29 30 31 32 33 34	0 (2 (622)		27
30 31 32 33 34			28
31 32 33 34			29
32 33 34		1	30
33 34			31
34		9	32
			33
35			34
			35

FLOW RATES

Sharp edged orifice

A = area

Q = volume flow rate

C_d = discharge coefficient

$$Q = AC_d \sqrt{2gh}$$

Execution:

h/RUN/A/RUN/C_d/RUN/Q

In S.I. units; g taken as 9.81ms⁻².

X		00
#	3	01
1	1	02
9	9	03
site	Α	04
6	6	05
2	2	06
=	-	07
√x	1	08
X		09
stop	0	10
X		11
stop	0	12
= 10	-	13
stop	0	14
	Α	15
goto	2	16
0	0	17
0	0	18
		19
ino	tuo	20
\ AS \ V	UR	21
	14	22
		23
lenoi	oit	24
1<.0	.8	25
		26
1 1 1 1	Z= -	27
		28
		29
		30
		31
		32
		33
		34
		35

FLOW RATES

Venturi

Subscript 1 refers to tube Subscript 2 refers to throat p = static pressure

a = area

u = velocity of fluid

 ρ = density

$$u = \sqrt{\frac{2(p_1 - p_2)}{\rho \left[\left(\frac{a_1}{a_2} \right)^2 - 1 \right]}}$$

Execution:

 a_1 / RUN / a_2 / RUN / ρ / RUN / p_1 / RUN / p_2 / RUN / u

Restrictions:

$$a_1 > a_2, p_1 > p_2$$
 or

$$a_1 < a_2, p_1 < p_2$$

÷	G	00
stop	0	01
X		02
_	F	03
#	3	04
1	1	05
X		06
stop	0	07
÷	G	80
X		09
(6	10
stop	0	11
_	F	12
stop	0	13
+	Е	14
) me	6	15
se=arto	-	16
\sqrt{x}	1	17
stop	0	18
•	Α	19
goto	2	20
0	U	21
0	0	22
	7. 72	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

PIPE FLOW

L = length

D = diameter

C_f = skin inertia coefficient

 ρ = density

U_m = mean velocity

pressure drop = $2 \frac{L}{D} C_f \rho U_m^2$

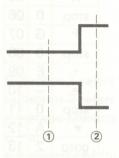
Execution:

 U_m /RUN / ρ / RUN / C_f / RUN / L / RUN / D / RUN / pressure drop

X		00
X	•	01
stop	0	02
X	•	03
stop	0	04
X	•	05
stop	0	06
•	G	07
stop	0	08
+	E	09
=	-	10
stop	0	11
•	Α	12
goto	2	13
0	0	14
0	0	15
u) ?	2	16
		17
1203	0.0	18
		19
gová	2	20
Gno	d Ob	21
MIRA		22
		23
b wan	nin	24
		25
×1071 \	9 82	26
CELLII CIE		27
n-etin		28
		29
		30
		31
		32
		33
		34
		35

PIPE FLOW

Sudden expansion



Head loss =
$$\frac{(u_1 - u_2)^2}{2q}$$
 (i)

$$\Delta h = \frac{u_1^2}{2g} \left(1 - \frac{A_1}{A_2} \right)^2$$
 (ii)

Execution:

- (i) $u_1 / RUN / u_2 / RUN / head loss$ (post execution with / RUN / RUN / before entering new data)
- (ii) u₁ / RUN / RUN / A₁ / RUN / A₂ / RUN / head loss

In S.I. units; g taken as 9.81ms².

1000	F	00
stop	0	01
X		02
÷	G	03
#	3	04
1	1	05
9	9	06
ei in	Α	07
6	6	08
2	2	09
X	4	10
(6	11
stop	0	12
÷	G	13
stop	0	14
-	F	15
#	3	16
1	1	17
X		18
)	6	19
=	_	20
stop	0	21
o▼ 1/8	Α	22
goto	2	23
0	0	24
0	0	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

RISE DIFFUSER



$$\Delta p = \frac{\rho u_1^2}{2} \left[1 - \left(\frac{A_1}{A_2} \right)^2 \right]$$

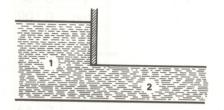
Execution:

 A_1 / RUN / A_2 / RUN / u_1 / RUN / ρ / RUN / Δp

$$(A_2 > A_1 \text{ for +ve } \Delta p)$$

	_	
÷	G	00
stop	0	01
X		02
_	F	03
#	3	04
1	1	05
	F	06
X	•	07
(6	08
stop	0	09
X	•	10
)	6	11
X		12
stop	0	13
÷	G	14
#	3	15
2	2	16
= %	-	17
stop	0	18
S V 45	Α	19
goto	2	20
0	0	21
0.00	0	22
MIIA V		23
		24
nits; g t		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

SLUICE GATE



$$F_2^2 = \frac{u_2^2}{gh_2}$$
 (i)

$$=\frac{2h_1^2}{h_2(h_1+h_2)}$$
 (ii)

Execution:

(i) $u_2 / RUN / h_2 / RUN / F_2^2$

In S.I. units; g taken as 9·81ms⁻².

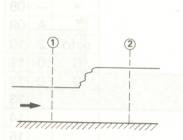
-		
X		00
*	G	01
stop	0	02
*	G	03
#	3	04
9	9	05
•	Α	06
8	8	07
1	1	80
=	_	09
stop	0	10
-	Α	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
- X	S	18
		19
		20
	3 200	21
		22
and the second	12	23
0		24
- 0		25
		26
		27
1		28
		29
		30
		31
		32
		33
		34
		35
		-

Sluice gate (cont.)

(ii) $h_2 / RUN / h_1 / RUN / F_2^2$

÷ G 00 stop 0 01 + E 02 (6 03 X · 04) 6 05 ÷ G 06 + E 07 = - 08 ▼ A 09 goto 2 10 0 0 11 0 0 12 13 14 15 16 16 17 18 19 20 21 22 23 24 25 24 25 26 27 28 29 30 31 31 32 33 34 35			
+ E 02 (6 03	÷	G	00
(6 03			
X		E	
) 6 05		-	
 ÷ G 06 + E 07 = - 08 ▼ A 09 goto 2 10 0 0 11 0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 		•	
+ E 07 = - 08 ▼ A 09 goto 2 10 0 0 11 0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 24 25 26 27 28 29 30 31 32 33 34			
=			
▼ A 09 goto 2 10 0 0 11 0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34		E	
goto 2 10 0 0 11 0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 31 32		_	
0 0 11 0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	•		
0 0 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	3100		
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		4	
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		16	
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
20 21 22 23 24 25 26 27 28 29 30 31 32 33		1	
21 22 23 24 25 26 27 28 29 30 31 32 33		- 8	
22 23 24 25 26 27 28 29 30 31 32 33		- 2	
23 24 25 26 27 28 29 30 31 32 33 34	1 + 141.	4	21
24 25 26 27 28 29 30 31 32 33	12. 150		
25 26 27 28 29 30 31 32 33		,8	
26 27 28 29 30 31 32 33 34		1 1	
27 28 29 30 31 32 33 34	Diffy	A	
28 29 30 31 32 33 33	11466	in in	
29 30 31 32 33 34			
30 31 32 33 33	713.00	213	
31 32 33 34	MUH V	10%	
32 33 34	1000	0	
33	101		OF REAL PROPERTY.
34			and the state of the state of
		A	-
35	81	4	CONTRACTOR DESCRIPTION AND ADDRESS.
The same of the sa	stop	- 0	35

HYDRAULIC JUMP



$$F_1^2 = \frac{h_2 (h_1 + h_2)}{2h_1^2}$$
 (i)

$$F_2^2 = \frac{h_1 (h_1 + h_2)}{2h_2^2}$$
 (ii)

Execution:

- (i) $h_2 / RUN / h_1 / RUN / F_1^2$
- (ii) $h_1 / RUN / h_2 / RUN / F_2^2$

 ÷ G 00 stop 0 01 + E 02 (6 03 × 04) 6 05 ÷ G 06 # 3 07 2 2 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 	The second second second second second		
+ E 02 (6 03 X	÷	G	00
(6 03 X	stop	0	01
X	+	Е	02
) 6 05 ÷ G 06 # 3 07 2 2 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	(6	03
 ∴ G 06 # 3 07 2 2 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 	X		04
2 2 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34)	6	05
2 2 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34	÷	G	06
=		3	07
stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	2	2	08
▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 16 17 18 19 20 21 22 23 24 25 25 26 27 28 29 30 31 32 33 34	=	_	09
goto 2 12 0 0 13 0 0 14 15 16 16 17 18 19 20 21 22 23 23 24 25 26 27 28 29 30 31 31 32 33 34	stop	0	10
0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	•		11
0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	goto	2	12
0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	0	0	13
16 17 18 19 20 21 22 23 23 24 25 26 27 28 29 30 31 32 33 34	0	0	14
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			15
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			16
19 20 21 22 23 24 25 26 27 28 29 30 31 31 32 33	HURY		17
20 21 22 23 24 25 26 27 28 29 30 31 31 32 33			18
21 22 23 24 25 26 27 28 29 30 31 31 32 33			19
22 23 24 25 26 27 28 29 30 31 31 32 33			20
23 24 25 26 27 28 29 30 31 31 32 33			21
24 25 26 27 28 29 30 31 32 33 34			22
25 26 27 28 29 30 31 32 33 34			23
26 27 28 29 30 31 32 33 34			24
27 28 29 30 31 32 33 34			25
28 29 30 31 32 33 34			26
29 30 31 32 33 34			27
30 31 32 33 34			28
31 32 33 34			
32 33 34			30
33 34			31
34			32
			33
35			34
			35

COMPRESSIBLE FLOW

Perfect gas relationships:

M = mach number

 γ = ratio of specific heats = 1.405 for dry air

$$\frac{T}{T_o} = \left(1 - \frac{(\gamma - 1) M^2}{2}\right)$$

$$\frac{P}{P_0} = \left(1 - \frac{(\gamma - 1) M^2}{2}\right)^{\frac{\gamma}{\gamma - 1}}$$

$$\frac{\rho}{\rho_o} = \left(1 - \frac{(\gamma - 1) \, \mathsf{M}^2}{2}\right)^{\frac{1}{\gamma - 1}}$$

Execution:

M/RUN/ γ /RUN/ $\frac{T}{T_o}$ /RUN/ $\frac{P}{P_o}$ /RUN/ $\frac{\rho}{\rho_o}$

X		00
-	F	01
(6	02
X	-	03
stop		04
sto	9,2	05
)	3.7	06
: ÷ : 08	G	07
#		08
2	2	09
+	E	10
#	3	11
1	1	12
=	-	13
stop	0	14
In	4	15
÷	G	16
(6	17
rcl	5	18
_	F	19
#	3	20
1	1	21
=	-	22
00)	6	23
X		24
•	Α	25
MEx	5	26
=	_	27
	Α	28
e ^x	4	29
stop	0	30
rcl	5	31
VE ME	-	32
₩	Α	33
ex	4	34
stop	0	35

THERMODYNAMICS

Polytropic process

p = pressure

v = volume

n = index

T = absolute temperature

R = gas constant

 $pv^n = constant$

To find index or final pressure or volume

(i)
$$p_2 = p_1 \left(\frac{v_1}{v_2}\right)^n$$

(ii)
$$v_2 = v_1 \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}$$

(iii)
$$n = -\frac{\log\left(\frac{p_2}{p_1}\right)}{\log\left(\frac{v_2}{v_1}\right)}$$

Execution:

- (i) $n/RUN/v_1/RUN/v_2/RUN/p_1/RUN/p_2$
- (ii) $n/\div/RUN/p_1/RUN/p_2/RUN/v_1/RUN/v_2$
- (iii) / $\triangle \triangledown$ / goto / 1 / 9 / p₁ / RUN / p₂ / RUN / v₁ / RUN / v₂ / RUN / n

X	1	00
(6	01
stop	0	02
÷	G	03
stop	0	04
=	-	05
ln ·	4	06
)	6	07
=	_	80
▼	Α	09
e ^x	4	10
X	•	11
stop	0	12
=	_	13
stop	0	14
•	Α	15
goto	2	16
0	0	17
0	0	18
*	G	19
stop	0	20
=	-	21
In	4	22
ino	G	23
(6	24
stop	0	25
÷	G	26
stop	0	27
=	_	28
In	4	29
)	6	30
_	F	31
.=	_	32
stop	0	33
=	-	34
=	-	35

THERMODYNAMICS

Polytropic process

To find work

work =
$$\frac{p_2 v_2 - p_1 v_1}{1 - p_1}$$
 (i)

$$= \frac{R(T_2 - T_1)}{1 - n}$$
 (ii)

for a perfect gas

Execution:

- (i) p₁/RUN / v₁ / RUN / p₂ / RUN / v₂ / RUN / n / RUN / work
- (ii) R / RUN / T₁ / RUN / RUN / T₂ / RUN / n / RUN / work

2	00
1	01
0	02
F	03
6	04
5	05
0	06
٠	07
0	80
6	09
G	10
	11
	12
	13
	14
	15
	16
F	17
-	18
	19
	20
	21
	22
0	23
	24
	25
	26
	27
	28
	29
	30
	31
	32
	33
	34
	35
	0 F 6 5 0

HEAT CONDUCTION SHAPE FACTORS

Cylinder

 r_i = inside radius

 r_o = outside radius

L = length

F = shape factor

$$F = \frac{2\pi L}{\ln\left(\frac{r_o}{r_i}\right)}$$

Execution:

r_o/RUN/r_i/RUN/L/RUN/F

÷	G	00
stop	0	01
og T alo	-	02
In	4	03
÷	G	04
X		05
stop	0	06
X	•	07
#	3	80
3	3	09
6	6	10
0	0	11
-50,500.0	-	12
-	Α	13
D→R	3	14
stop	0	15
	Α	16
goto	2	17
0	0	18
0	0	19
THE STATE	19	20
(a) Ne		21
VILLE \	Till I	22
RUN	G	23
		24
59-50		25
		26
www		27
-		28
in	4	29
	8	30
		31
		32
stoni -		33
		34
		35
		The same of the same of

HEAT CONDUCTION SHAPE FACTORS

Sphere

 r_i = inside radius r_o = outside radius

$$F = \frac{4\pi r_o r_i}{r_o - r_i}$$

Execution:

r_i/RUN/r_o/RUN/F

÷	G	00
	F	01
(6	02
stop	0	03
÷	G	04
)	6	05
÷	G	06
X		07
#	3	08
7	7	09
2	2	10
0	0	11
=	_	12
•	Α	13
D→R	3	14
stop	0	15
	Α	16
goto	2	17
0	0	18
0	0	19
		20
	AU	21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

HEAT CONDUCTION SHAPE FACTORS

Horizontal disc

$$F = \frac{2.22 \text{ r}}{1 - \frac{\text{r}}{2.83D}}$$

Execution:

r/RUN/D/RUN/F

- 4	0		0	_
sto	2		00	-
÷	G		0.	
stop	0	_	02	
÷	G		03	
#	3		04	
2	2		05	
•	Α		06	
8	8		07	
3	3		80	
_	F		09)
#	3		10	
1	1		11	
_	F	I	12	
÷	G		13	
X			14	
rcl	5	T	15	
X		1	16	
#	3	1	17	
2	2	200	18	
	Α	T	19	
2	2		20	
2	2	-	21	1
=	_		22	1
stop	0		23	1
	Α		24	1
goto	2		25	1
0	0	+-	26	1
0	0	_	27	1
			28	١
		-	29	
		+-	30	
		1	31	
		-	32	
			33	
			34	
-			35	

HEAT CONDUCTION SHAPE FACTOR

Buried sphere

r = radius D = centre line depth

$$F = \frac{\pi r}{1 - \frac{r}{2D}}$$

Execution:

r/RUN/D/RUN/F

sto	2	00
•	G	01
stop	0	02
_	F	03
#	3	04
2	2	05
_	F	06
÷	G	07
X		80
rcl	5	09
X		10
#	3	11
3	3	12
6	6	13
0	0	14
du=/pv		15
•	Α	16
D→R	3	17
stop	0	18
•	Α	19
goto	2	20
0	0	21
0	0	22
		23
1940 60		24
APCAR		25
		26
1 24 13		27
		28
203 8710		29
73.5 VV		30
		31
236		32
21		33
37 / 6		34
		35

ACOUSTICS

Adding sound levels (and weighted sound levels) in dB (+ hourly average of sound level) (Log. r.m.s. addition)

$$L_n = 10 \log_{10} \frac{P_n}{P_r} = 4.3429448 \ln \frac{P_n}{P_r}$$

where P_r = reference s.p.l. of 2 x 10⁻⁵ Nm⁻²

Definitions:

$$L_{m} \oplus L_{n} = 4.34294 \text{ In} \left[exp \left(\frac{L_{m}}{4.34294} \right) + exp \left(\frac{L_{n}}{4.34294} \right) \right]$$

Noise level subtraction operator ⊖

$$L_{m} \ominus L_{n} = 4.34294 \text{ In } \left[exp \left(\frac{L_{m}}{4.34294} \right) - exp \left(\frac{L_{n}}{4.34294} \right) \right]$$

Weighting by time operator \otimes

$$L_n \otimes t_n = 4.34294 \text{ In } \left[t_n \exp \left(\frac{L_n}{4.34294} \right) \right]$$

Averaging over time

$$L_{av} = 4.34294 \text{ In } \left[\frac{1}{t} \sum_{k=1}^{n} t_k \exp \left(\frac{L_k}{4.34294} \right) \right]$$

$$t = t_1 + t_2 + \cdots + t_n$$

Weighting table ('A' weighting)

$W_f(dB)$	f(kHz)	W _f (dB)
39	1	0
26	2	. 1
16	4	1
10	8	1
3		
	39 26 16 10	39 1 26 2 16 4 10 8

÷	G	00
#	3	01
8	8	02
	Α	03
6	6	04
8	8	05
5	5	06
8	8	07
9	9	80
=	_	09
▼	Α	10
e ^x	4	11
X		12
stop	0	13
+	E	14
rcl	5	15
=	-	16
sto	2	17
\sqrt{x}	1	18
In	4	19
X		20
#	3	21
8	8	22
•	Α	23
6	6	24
8	8	25
5	5	26
8	8	27
9	9	28
=	-	29
stop	0	30
•	Α	31
goto	2	32
0	0	33
0	0	34
		35

Pre-execution:

/ ▲▼ / ▲▼ / goto / 0 / 0 / C/CE / ▲▼ / sto / to clear memory

Execution:

(i) Adding noise/sound levels:

 L_1 / RUN / RUN / L_2 / RUN / RUN / $L_1 \oplus L_2$ / L_3 / RUN / RUN / $L_1 \oplus L_2 \oplus L_3 \cdots$

(ii) Subtracting noise levels:

 L_1 / RUN / RUN / L_2 / RUN / - / RUN / $L_1 \ominus L_2$ (add or subtract levels at will)

(iii) Adding and weighting noise levels:

 $L_1/-/W_1/RUN/RUN/L_1-W_1/L_2/-/W_2/RUN/RUN/(L_1-W_1) \oplus (L_2-W_2) \cdots$ (see table for W_t)

Post execution:

/ AV / Goto / 1 / 4 / 9/CE / AV / MEx / ÷ / n / RUN / Lweighted

where n = no, of levels entered.

(iv) Time averaged noise levels:

 L_1 / RUN / X / t_1 / RUN / $L_1 \otimes t_1$ / L_2 / RUN / X / t_2 / RUN / ($L_1 \otimes t_1$) \oplus ($L_2 \otimes t_2$) \cdots

Post execution:

/ AV / Goto / 1 / 4 / C/CE / AV / MEx / ÷ / t / RUN / Lay

(v) Hourly averaged noise level:

Add 24 hourly levels using (i) then post-execution

Post execution:

/ AV / Goto / 1 / 4 / $^{\circ}$ /CE / AV / MEx / \div / 24 / RUN / $^{\perp}$

DECIBEL CONVERSION

$$A_{dB} = 10 \log_{10} \frac{P_2}{P_1} = 20 \log_{10} \frac{E_2}{E_1}$$

= 20 \log_{10} \frac{I_2}{I_1}

$$P_2 = P_1 \text{ antilog}_{10} \frac{AdB}{10}$$

$$E_2 = E_1 \text{ antilog}_{10} \frac{AdB}{20}$$

$$I_2 = I_1 \text{ antilog}_{10} \frac{\text{AdB}}{20}$$

Neper conversion:

$$A_n = \frac{1}{2} \ln \frac{P_2}{P_1} = \ln \frac{E_2}{E_1} = \ln \frac{I_2}{I_1}$$

$$P_2 = P_1 \exp 2A_n$$

$$E_2 = E_1 \exp A_n$$

$$I_2 = I_1 \exp A_n$$

Ratio to dB or nepers:

Execution:

$$P_{2}/\div/P_{1}/=/\blacktriangle \blacktriangledown/\sqrt{x}/$$
or $E_{2}/\div/E_{1}/=/$
or $I_{2}/\div/I_{1}/=/$

$$r/RUN/A_{dB}$$

In	4	00
stop	0	01
X		02
#	3	03
8	8	04
•	Α	05
6	6	06
8	8	07
5	5	80
8	8	09
9	9	10
=	_	11
stop	0	12
•	Α	13
goto	2	14
0	0	15
0	0	16
•	G	17
#	3	18
8	8	19
. J . MI	Α	20
6	6	21
8	8	22
5	5	23
8	8	24
9	9	25
00 = 030	_	26
stop	0	27
•	Α	28
e ^x	4	29
X	•	30
stop	0	31
V	Α	32
goto	2	33
1	1	34
7	7	35

dB or nepers to ratio:

Pre-execution:

dB to ratio:

▲▼ / ▲▼ / goto / 1 / 7 / first time only

nepers to ratio:

▲▼ / ▲▼ / goto / 2 / 8 / every time

Execution:

dB to ratio:

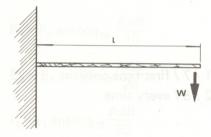
$$A_{dB} / RUN / A_{n} / RUN / r \begin{cases} / X / P_{1} / = / P_{2} \\ or / E_{1} / = / E_{2} \\ or / I_{1} / = / I_{2} \\ or / = / r^{2} \end{cases}$$

Always use / = / even if no other result is required.

nepers to ratio:

A_n / RUN / r and continue with alternatives as above.

Beam with one fixed end and load W at free end



end slope =
$$\frac{W\ell^2}{2EI}$$

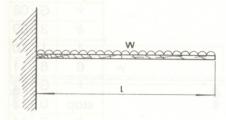
end deflection =
$$\frac{W\ell^3}{3EI}$$

Execution:

% / RUN / W / RUN / E / RUN / I / RUN / slope / RUN / deflection

sto	2	00
X		01
X		02
stop	0	03
÷	G	04
stop	0	05
*	G	06
stop	0	07
÷	G	08
#	3	09
2	2	10
÷	G	11
stop	0	12
#	3	13
1	1	14
9 m	A	15
5	5	16
X		17
rcl	5	18
A T ME	-	19
stop	0	20
•	Α	21
goto	2	22
0	0	23
0	0	24
		25
		26
stop	Ü	27
		28
		29
		30
	9	31
19	,94	32
goto	2	33
		34
7		35

Beam with one fixed end and distributed loading W



end slope =
$$\frac{W\ell^2}{6EI}$$

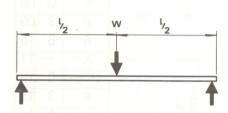
end deflection =
$$\frac{W\ell^3}{8EI}$$

Execution:

2 / RUN / W / RUN / E / RUN / I / RUN / slope / RUN / deflection

sto	2	00
X		01
X	i	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	80
#	3	09
6	6	10
X	•	11
stop	0	12
#	3	13
•	Α	14
7	7	15
5	5	16
X	•	17
rcl	5	18
at= **	Ois.	19
stop	0	20
	Α	21
goto	2	22
0	0	23
0	0	24
19A		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Simply supported beam with central load W



end slope =
$$\frac{W\ell^2}{16EI}$$

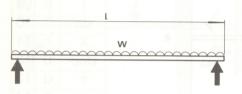
central deflection =
$$\frac{W\ell^3}{48EI}$$

Execution:

L / RUN / W / RUN / E / RUN / I / RUN /
end slope / RUN / central deflection

sto	2	00
X		01
X		02
stop	0	03
*	G	04
stop	0	05
*	G	06
stop	0	07
•	G	80
#	3	09
1	1	10
6	6	11
÷	G	12
stop	0	13
#	3	14
3	3	15
X	•	16
rcl	5	17
1 W=	-	18
stop	0	19
▼	Α	20
goto	2	21
0	0	22
0	0	23
19/13		24
\ MUB		25
		26
		27
		28
		29
		30
		31
		32
		33
		33 34 35

Simply supported beam with distributed loading W



end slope =
$$\frac{W\ell^2}{24EI}$$

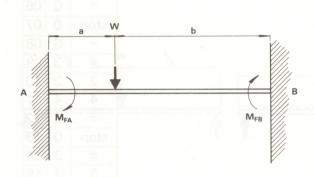
central deflection =
$$\frac{5W\ell^3}{384EI}$$

Execution:

% / RUN / W / RUN / E / RUN / I / RUN /
end slope / RUN / central deflection

sto	2	00
X	•	01
X		02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	08
#	3	09
2	2	10
4	4	11
÷	G	12
stop	0	13
#	3	14
3	.3	15
	Α	16
2	2	17
X		18
rcl	5	19
= 39	_	20
stop	0	21
V59	Α	22
goto	2	23
0	0	24
0	0	25
		26
i eton		27
		28
- ston	i	29
198	A	30
ento	3	31
		32
		33
		34
		35

Beam fixed at both ends with load W at a distance from end A



$$M_{FA} = \frac{Wb^2 a}{\ell^2}$$

$$M_{FB} = \frac{Wa^2b}{\ell^2}$$

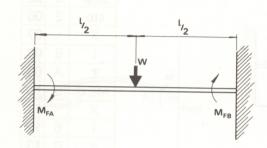
$$\ell = a + b$$

Execution:

b/RUN/a/RUN/W/RUN/l/RUN/_{MFA}/RUN/_{MFB}

sto	2	00
X		01
X		02
rcl	5	03
X		04
(6	05
stop	0	06
÷	G	07
rcl	5	08
)	6	09
sto	2	10
X		11
stop	0	12
÷	G	13
(6	14
stop	0	15
X		16
)	6	17
_	F	18
X		19
stop	0	20
rcl	5	21
_	F	22
=	-	23
stop	0	24
-	Α	25
goto	2	26
0	0	27
0	0	28
		29
-	1	30
		31
		32
		33
		34
		35

Beam with two fixed ends and central loading W



Fixed end moments

$$M_{FA} = -\frac{W\ell}{8}$$

$$M_{FB} = \frac{W\ell}{8}$$

Central deflection

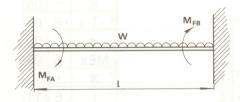
$$d = \frac{W\ell^3}{192EI}$$

Execution:

W / RUN / L / RUN / E / RUN / I / RUN / MFA / RUN / MFB / RUN / d

	-	_
÷	G	00
#	3	01
8	8	02
X	THE	03
stop	0	04
sto	2	05
X		06
(6	07
	Α	08
MEx	5	09
X		10
)	6	11
÷	G	12
#	3	13
2	2	14
4	4	15
ini i n b	G	16
stop	0	17
÷	G	18
stop	0	19
=		20
•	Α	21
MEx	5	22
_	F	23
_	F	24
stop	0	25
= 170	1	26
stop	0	27
rcl	5	28
stop	0	29
▼	Α	30
goto	2	31
0	0	32
0	0	33
		34
		35
		00

Beam between two fixed ends with evenly distributed total load W



Fixed end moments

$$M_{FA} = -\frac{W\ell}{12}$$

$$M_{FB} = \frac{W\ell}{12}$$

Central deflection

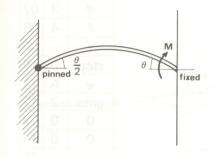
$$d = \frac{W\ell^3}{384EI}$$

Execution:

 $W/RUN/2/RUN/E/RUN/I/RUN/M_{FA}/RUN/M_{FB}/RUN/d$

÷	G	00
#	3	01
1	1	02
2	2	03
X	٠	04
stop	0	05
sto	2	06
X		07
(6	80
•	6 A 5	09
MEx	5	10
×	•	11
)	6	12
÷	G	13
#	3	14
3	3	15
2	2	16
nc i n b	G	17
stop	0	18
÷g	G	19
stop	0	20
=	-	21
•	Α	22
MEx	5	23
<u> </u>	F	24
- 1	F F	25
stop	0	26
= 10	1	27
stop	0	28
rcl	5	29
stop	0	30
•	Α	31
goto	2	32
0	0	33
0	0	34
		35

Beam with one fixed end, one pinned end. Effect of rotation at fixed end.



M = applied bending moment

end slope =
$$\frac{M\ell}{3EI}$$

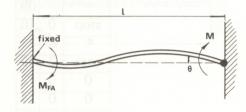
Execution:

M / RUN / l / RUN / E / RUN / I / RUN / end slope

X		00
stop	0	01
ani i	G	02
stop	0	03
•	G	04
stop	0	05
÷	G	06
#	3	07
3	3	08
=	-	09
stop	0	10
. *	Α	11
goto	2	12
0	0	13
0	0	14
	0	15
		16
		17
- 0		18
		19
2211 36 .		20
		21
K = 8 es		22
		23
100		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Beam with one fixed end and one pinned end

effect of rotation at pinned end



Moment at fixed end A, = $M_{FA} = \frac{M}{2}$

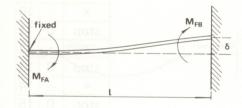
end slope
$$\theta = \frac{M\ell}{4EI}$$

Execution:

M / RUN / l / RUN / E / RUN / I / RUN / end slope

X 00 stop 0 01 G 02 stop 0 05 G 06 # 3 07 4 4 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 34 35			
 ÷ G O2 stop O O3 ÷ G O4 stop O O5 ÷ G O6 # 3 O7 4 4 08 = - 09 stop O 10 ▼ A 11 goto 2 12 O O 13 O O 14 15 16 17 18 19 20 21 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 	X		00
 ÷ G 02 stop 0 03 ÷ G 04 stop 0 05 ÷ G 06 # 3 07 4 4 08 = - 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 		0	01
÷ G O4 stop O O5 ÷ G O6 # 3 O7 4 4 08 = - 09 stop O 10 ▼ A 11 goto 2 12 O O 13 O O 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34		G	02
stop 0 05	stop	0	03
stop 0 05 ÷ G 06 # 3 07 4 4 08 = — 09 stop 0 10 ▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	÷	G	04
 	stop	0	05
4 4 08 =		G	06
=	#	3	07
=	4	4	08
▼ A 11 goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	=	_	
goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	stop	0	10
goto 2 12 0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	-	Α	11
0 0 13 0 0 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		2	
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		0	13
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	14
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0		15
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	2	4.	
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
20 21 22 23 24 25 26 27 28 29 30 31 32 33			18
21 22 23 24 25 26 27 28 29 30 31 32 33			19
22 23 24 25 26 27 28 29 30 31 32 33	ed bel		20
23 24 25 26 27 28 29 30 31 32 33			21
24 25 26 27 28 29 30 31 32 33 34	SMT	ando	22
25 26 27 28 29 30 31 32 33 34			23
26 27 28 29 30 31 32 33 34			24
27 28 29 30 31 32 33 34	- 115	1000	25
28 29 30 31 32 33 34	laran l	W.F	26
29 30 31 32 33 34	9	1648	
30 31 32 33 34	SLOS	10	
31 32 33 34	101	-	
32 33 34	1100	U	30
33 34	7	8	31
34	2011		32
	- 1		33
35	- 9		-
			35

Effect of end displacement on beam fixed at both ends



Moments at fixed ends due to displacement δ

$$M_{FA} = M_{FB} = \frac{+6EI\delta}{\ell^2}$$

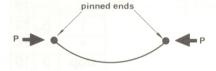
Execution:

E/RUN/I/ RUN/δ/RUN/ℓ/RUN/M_{FA}

X		00
stop	0	01
X		02
stop	0	03
X	•	04
stop	0	05
X		06
#	3	07
6	6	08
÷	G	09
(6	10
stop	0	11
X		12
)	6	13
=	_	14
stop	0	15
•	Α	16
goto	2	17
0	0	18
0	0	19
lesiji	5 7	20
anin		21
The same	1.10	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35
		-

STRUTS

Critical load — strut with two pinned ends



$$P_{crit.} = critical load = \frac{\pi^2 EI}{\varrho^2}$$

Execution:

l/RUN/E/RUN/I/RUN/Porit

÷	G	00
#	3	01
3	3	02
57.00	Α	03
1	1	04
4	4	05
1	1	06
6	6	07
÷	G	08
X		09
X	·	10
stop	0	11
X	1.	12
stop	0	13
=	4	14
stop	0	15
•	Α	16
goto	2	17
0	0	18
0	0	19
		20
L = gab		21
		22
180	13410	23
		24
3 / 3 / 9		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Critical load for strut fixed at one end, pinned at other end



$$P_{crit.} = \frac{2\pi^2 EI}{\ell^2}$$

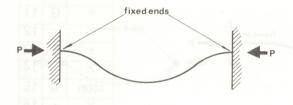
Execution:

l/RUN/E/RUN/I/RUN/Porit.

•	G	00
#	3	01
3	3	02
	Α	03
1	1	04
4	4	05
1	1	06
5	5	07
9	9	80
2	2	09
6	6	10
÷	G	11
X		12
+	Е	13
X	•	14
stop	0	15
X		16
stop	0	17
=	_	18
stop	0	19
•	Α	20
goto	2	21
0	0	22
0	0	23
1/3/	illi	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Strut with two fixed ends



$$P_{crit.} = \frac{4\pi^2 EI}{\ell^2}$$

Execution:

2 / RUN / E / RUN / I / RUN / P_{crit.}

÷	G	00
#	3	01
6	6	02
128110	A	03
2	2	04
8	8	05
3	3	06
2	2	07
÷	G	08
X		09
X		10
stop	0	11
Х		12
stop	0	13
=	_	14
stop	0	15
•	Α	16
goto	2	17
0	0	18
0	0	19
		20
		21
7 1 73 1 1	27.10	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS CAMINT TO M

Critical load for strut with one fixed end and one free end



$$P_{crit.} = \frac{E1\pi^2}{(2\ell)^2}$$

Execution:

& / RUN / E / RUN / I / RUN / Ports.

÷	0	00
	G	00
#	3	01
9	9	02
0	0	03
÷	G	04
=	-	05
•	Α	06
D→R	3	07
X	•	80
X	•	09
stop	0	10
X	•	11
stop	0	12
=	_	13
stop	0	14
•	Α	15
goto	2	16
0	0	17
0	0	18
		19
150	tub	20
9 1 + 1 1	9115	21
	lan:	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35
	1	1

TORSION OF THIN WALLED TUBE

Torque =
$$2\pi r^3 t G \frac{\theta}{L}$$

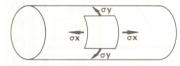
$$\frac{\theta}{L}$$
 = twist per unit length = $\frac{\text{angular deflection}}{\text{length}}$

Execution:

r/RUN/t/RUN/G/RUN/ $\frac{\theta}{L}$ /RUN/torque

X		00
(6	01
×		02
)	6	03
X	,	04
#	3	05
3	3	06
6	6	07
0	0	08
X		09
stop	0	10
X	•	11
stop	0	12
X	0	13
stop	0	14
8150	+	15
.▼	Α	16
D→R	3	17
stop	0	18
V	Α	19
goto	2	20
0	0	21
0	0	22
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CYLINDRICAL PRESSURE VESSEL



Longitudinal stress $\sigma_x = \frac{pd}{4t}$

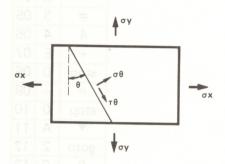
Hoop stress $\sigma_y = \frac{pd}{2t}$

Execution:

p/RUN/d/RUN/t/RUN/ σ_x /RUN/ σ_y

X		00
	0	01
stop ÷	G	02
stop	0	03
÷	G	04
#	3	05
4	4	06
+/	E	07
stop	0	80
//150	-	09
stop	0	10
•	Α	11
goto	2	12
0	0	13
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COMPLEX STRESSES



$$\sigma_{\theta} = \frac{\sigma_{x} + \sigma_{y}}{2} + \frac{\sigma_{x} - \sigma_{y}}{2} \cos 2\theta$$

$$\tau_{\theta} = \frac{\sigma_{x} - \sigma_{y}}{2} \sin 2\theta$$

Execution:

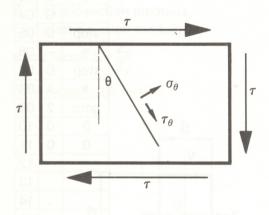
 $\sigma_{\rm x}$ / + / $\sigma_{\rm y}$ / RUN / θ / RUN / σ_{θ} / θ / $\Delta \Psi$ / MEx/ RUN / τ_{θ}

For angle θ in degrees use / $\blacktriangle \blacktriangledown$ / $D \rightarrow R$ / after entering θ each time.

For negative θ use /-/=/ after third / RUN / to give correct sign of τ_{θ} .

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stop	0	10
sin	7 • E F	11
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+	E	13
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+	E	15
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rcl	5	19
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rcl	5	25
sin	7	26
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X		28
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rcl	5	30
cos	8	31
)	6	32
+	Е	33
=		34
stop	0	35
		-

COMPLEX STRESSES



$$\sigma_{\theta} = \tau \sin 2\theta$$
$$\tau_{\theta} = -\tau \cos 2\theta$$

Execution:

 θ / RUN / τ / RUN / τ_{θ} / RUN / σ_{θ}

For θ in degrees insert / \blacktriangledown / D \rightarrow R / at start of program or use / \blacktriangle \blacktriangledown / \blacktriangle \blacktriangledown / D \rightarrow R / after entering θ .

For negative θ , use / - / = / after third / RUN / to give correct sign of σ_{θ} .

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+ E 02 - F 03 + E 04 # 3 05 1 1 06 = - 07 sto 2 08 stop 0 09 X 10 (6 11 X 12 rcl 5 13 - F 14 = - 15 stop 0 16 rcl 5 17 X 18 - F 19 + E 20 # 3 21 1 1 22 = - 23 √x 1 24) 6 25 = - 26 stop 0 27 ▼ A 28 goto 2 29 0 0 30 0 0 31 32 33	sin	7	
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- F 14 = - 15 stop 0 16 rcl 5 17 X 18 - F 19 + E 20 # 3 21 1 1 22 = - 23 √x 1 24) 6 25 = - 26 stop 0 27 ▼ A 28 goto 2 29 0 0 30 0 0 31 32 33 34	rcl	5	
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▼ A 28 goto 2 29 0 0 30 0 0 31 32 33 34	stop	0	
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34			
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ELASTIC STRAIN ENERGY

Elastic strain energy:

- (i) In tension $\frac{\sigma^2}{2E}$
- (ii) In torsion $\frac{\tau^2}{2G}$

Execution:

- (i) $\sigma / RUN / E / RUN / energy$
- (ii) $\tau / RUN / G / RUN / energy$

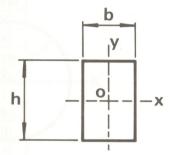
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· <u>·</u>	G	04
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stop	0	07
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goto	2	09
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ELASTIC AND PLASTIC SECTIONAL MODULI

 Z_e = elastic section modulus Z_p = plastic section modulus

shape factor
$$S = \frac{Z_p}{Z_e}$$

Solid rectangular section



$$Z_e = \frac{b^2 h}{6}$$

$$Z_p = \frac{b^2 h}{4}$$

$$S = 1.5$$

$$Z_e = \frac{bh^2}{6}$$

$$Z_p = \frac{bh^2}{4}$$

$$S = 1.5$$

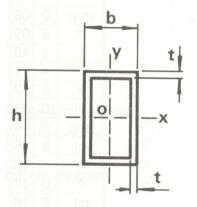
Execution:

b / RUN / h / RUN / Z_e for C_y / RUN / Z_p for C_y / RUN / Z_e for C_z / RUN / Z_p for C_z

sto	2	00
X X stop		01
X		02
stop	0	03
•	G	04
#	3	05
6	6	06
# 6 X		07
stop #	0	80
#	3	09
1	1 A 5 G	10
- Carrier - Carr	Α	11 12
5	5	12
÷	G	13
stop	0	14
rcl	5	15
X		16
÷	G	17
rcl	G 5	18
÷	G	19
. 5 . stop rcl X . rcl . #	3 A 3 7 5	20
	Α	21 22 23
3	3	22
3 7 5 X stop #	7	23
5	5	24
X		25
stop	0	26
#	3	27
1	1	28
	Α	29
5	5	30
5 = stop	1 A 5	31
stop	0	32
= 1	7	33
	_	34
=	_	35

PLASTIC AND PLASTIC SECTIONAL MODULI

Thin walled rectangular box



(t small compared to h and b)

Axis
$$C_y$$
: $Z_e = bt \left(h + \frac{b}{3} \right)$

$$Z_p = bt \left(h + \frac{b}{2} \right)$$

$$S = \frac{h + \frac{b}{2}}{h + \frac{b}{3}}$$

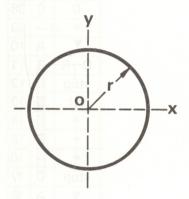
Execution:

 $h/RUN/b/RUN/t/RUN/Z_e/RUN/Z_p/RUN/S$

÷	G	00
stop	0	01
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=	_	07
•	Α	08
MEx	5	09
X		10
X		11
stop	0	12
X		13
(6	14
#	3	15
6	6	16
÷	G	17
_	F	18
+	E	19
rcl	5	20
÷ •	G	21
▼	Α	22
MEx	5	23
÷	G	24
=	2	25
÷ = •	Α	26
MEx	5	27
)	6	28
X		29
stop	0	30
rcl	5	31
= 1		32
stop	0	33
rcl	5	34
stop	0	35

PLASTIC SECTIONAL MODULI

Solid circular section



$$Z_e = \frac{\pi r^3}{4}$$

$$Z_p = \frac{4r^3}{3}$$

$$S = \frac{16}{3\pi} = 1.697653$$

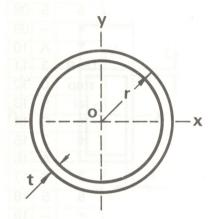
Execution:

r/RUN/Z_e/RUN/Z_p

	,	
X		00
(6	01
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)	6	03
X		04
sto	2	05
#	3	06
4	4	07
5	5	08
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	Α	10
D→R	3	11
stop	0	12
rcl	5	13
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#	3	15
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7	7	17
5	5	18
=	_	19
stop	0	20
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goto	2	22
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ELASTIC AND PLASTIC SECTIONAL MODULI

Thin walled circular tube



(t small compared to r)

$$Z_e = \pi r^2 t$$

$$Z_p = 4r^2t$$

$$S = \frac{4}{\pi} = 1.273240$$

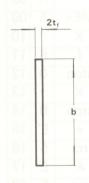
Execution:

r/RUN/t/RUN/Z_e/RUN/Z_p

X		00
X	•	01
stop	0	02
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sto	2	04
#	3	05
1	1	06
8	8	07
0	0	80
=	5-	09
•	Α	10
D→R	3	11
stop	0	12
rcl	5	13
+	Ε	14
+	E	15
=	-	16
stop	0	17
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goto	2	19
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ELASTIC AND PLASTIC SECTIONAL MODULI

Thin 1-section



(thickness small compared to overall dimensions)

$$Z_e = \frac{b^2 t_f}{3}$$

$$Z_p = \frac{b^2 t_f}{2}$$

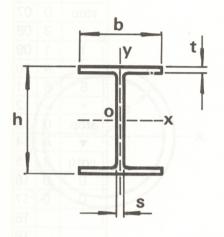
Execution:

 $b/RUN/t_f/RUN/Z_e/RUN/Z_p$

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stop	0	13
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goto	2	15
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ELASTIC AND PLASTIC SECTIONAL MODULI

Thin I-section



Axis
$$C_z$$
: $Z_e = h\left(bt + \frac{hs}{6}\right)$

$$Z_p = h\left(bt + \frac{hs}{4}\right)$$

$$S = \frac{bt + \frac{hs}{4}}{bt + \frac{hs}{6}}$$

Execution:

 $h/RUN/S/RUN/b/RUN/t/RUN/Z_e/RUN/Z_p/RUN/S$

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	X	•	10
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	stop	0	12
	X	•	13
	stop	0	14
	+	E	15
	rcl	5	16
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	rcl	5	18
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	rcl	5	33
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MEX	5	26
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